

# Interbasinal marker intervals — A case study from the Jurassic basins of Kachchh and Jaisalmer, western India

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**The Kachchh Basin and the Jaisalmer Basin are two neighboring Mesozoic sedimentary basins at the western margin of the Indian craton. The Jurassic succession of the Kachchh Basin is more complete and more fossiliferous than that of the Jaisalmer Basin. Consequently, intrabasinal correlation of the sedimentary units has been possible in the Kachchh Basin, but not in the Jaisalmer Basin. However, some marker beds existing in the Kachchh Basin can be recognized also in the Jaisalmer Basin. Ammonite evidence shows that they are time-equivalent. The following four units form marker intervals in both basins: (1) the pebbly rudstone unit with *Isastrea bernardiana* and *Leptosphinctes* of the Kaladongar Formation (Kachchh Basin) and the *Isastrea bernardiana*-bearing rudstone of the Jaisalmer Formation (Jaisalmer Basin) both represent transgressive systems tract deposits dated as Late Bajocian; (2) bioturbated micrites with anomalodesmatan bivalves within the Goradongar Yellow Flagstone Member (Kachchh Basin) and bioturbated units in the Fort Member (Jaisalmer Basin) represent maximum flooding zone deposits of the Middle to Late Bathonian; (3) trough-crossbedded, sandy pack- to grainstones of the Raimalro Limestone Member (Kachchh Basin) and the basal limestone-sandstone unit of the Kuldhar section of the Jaisalmer Formation (Jaisalmer Basin) correspond to Late Bathonian transgressive systems tract deposits; and (4) ferruginous ooid-bearing carbonates with hardgrounds of the Dhosa Oolite member (Kachchh Basin) and the middle part of the Jajiya Member (Jaisalmer Basin) are Oxfordian transgressive systems tract deposits. The fact that in both basins similar biofacies prevailed during certain time intervals demonstrates a common control of their depositional history. As the two basins represent different tectonic settings, the most likely controlling factors were the relative sea-level changes produced by eustatic processes, a common subsidence history of the northwestern margin of the Indian craton, and the paleoclimate.**

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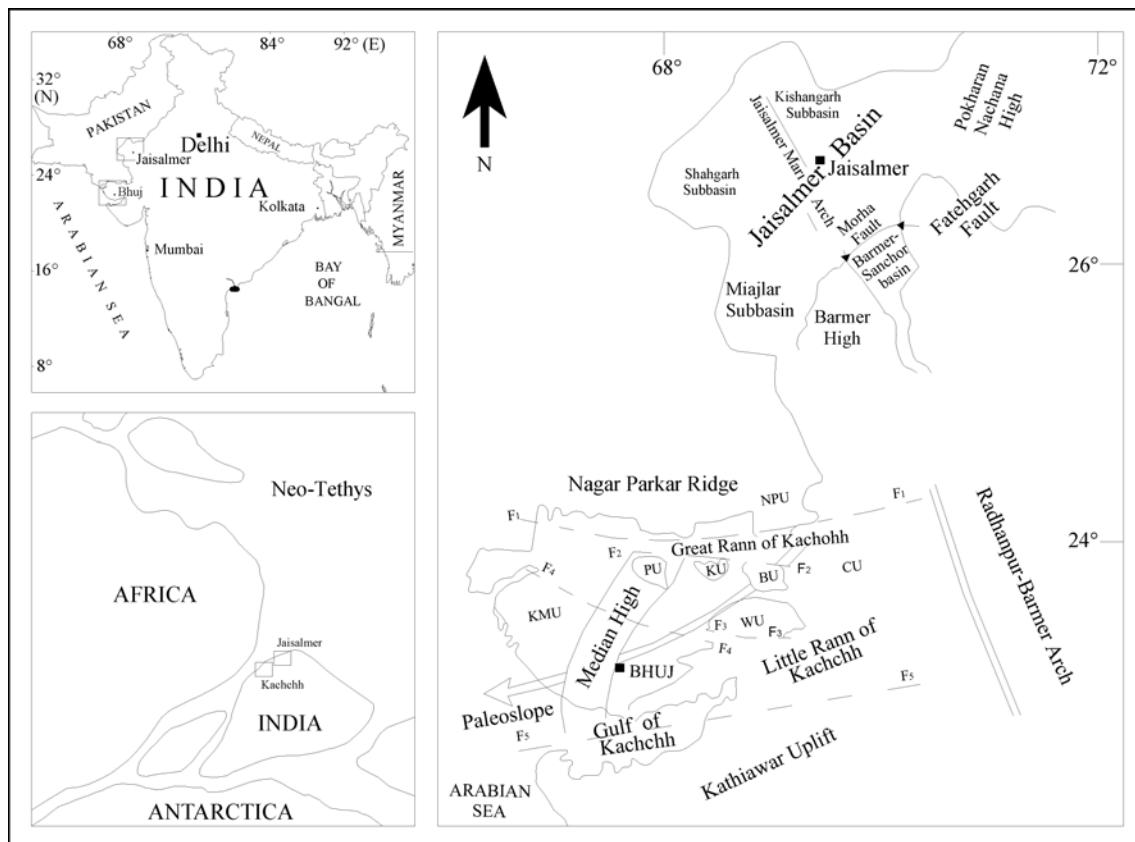
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The sedimentary basins of Kachchh and Jaisalmer are neighboring Jurassic basins situated on the northwestern part of the Indian craton (Figure 1). The sea started to flood both basins simultaneously in the late Early Jurassic<sup>[4–7]</sup>. The Jurassic marine sedimentary succession has been biostratigraphically subdivided into fine time-intervals<sup>[8]</sup>, and the main depositional environments have been discussed by Fürsich and Oschmann<sup>[9]</sup> and Fürsich et al.<sup>[10–12]</sup>. Combining biostratigraphic evidence and paleoenvironmental analysis has allowed reconstructing the paleogeographic evolution of the area during the Jurassic period and identifying and evaluating relative sea-level changes.

The Jurassic sedimentary fill of the two basins ranges from fluvial sandstones and red beds and marginal marine siliciclastic sediments to shallow-marine mixed siliciclastics-carbonates, finally to shelf deposits domi-

nated by carbonates. The age of the sedimentary succession ranges from pre-Bajocian to Tithonian. Biswas<sup>[13]</sup>, on the basis of the facies pattern, which broadly divided the Kachchh Basin into western Kachchh (Pachchham Island and Kachchh Mainland) and eastern Kachchh (Khadir, Bela, Chorad islands and Wagad). Lithostratigraphically, the Jurassic rocks of the western Kachchh Basin have been grouped into seven formations: Kaladongar, Goradongar, Jhurio, Patcham, Chari, Katrol, and Umia (Figure 2). The coeval sediments of the eastern Kachchh Basin have been grouped into three formations, i.e., Khadir, Gadhada, and Washtawa in ascending order (Figure 3). The Jurassic succession of the Jaisalmer Basin has been accommodated in four formations; Lathi, Jaisalmer, Baisakhi, and Bhadesar in ascending order (Figure 2).

Of the two basins, the stratigraphic succession of the



**Figure 1** Map showing locations of Kachchh and Jaisalmer basins on the northwestern part of the Indian craton<sup>[1–3],1)</sup>. KMU, Kmu Mainland Uplift; WU, Wagad Uplift; PU, Pachham Uplift; KU, Khadir Uplift; BU, Bela Uplift; CU, Chorar Uplift; NPU, Nagar Parkar Uplift; F<sub>1</sub>, Nagar Parkar Fault; F<sub>2</sub>, Island Belt Fault; F<sub>3</sub>, South Wagad Fault; F<sub>4</sub>, Kachchh Mainland Fault; F<sub>5</sub>, North Kathiawar Fault.

1) Misra P C, Singh N P, Sharma D C, et al. Lithostratigraphy of west Rajasthan basins. Oil and Natural Gas Corporation, Dehradun, Unpublished report, 1993

Age	Western Kachchh			Jaisalmer		
Tithonian to Early Cretaceous	Umia Fm	Umia Plant Bed, Pars? Umia Ammonite Bed		Mokal Mb Kolar Dungar Mb	Bhadesar Fm	
Kimmeridgian to Portlandian	Katrol Fm	Upper Mb Middle Mb Lower Mb		Lanelia Mb Ludharwa Mb Rupsi Mb Baisakhi Mb	Baisakhi Fm	
Oxfordian		Dhosa Oolite Mb	Jajiyia Mb	Ooid bearing carbonate sediments with HGS		4
Callovian	Chari Fm	Dhosa Sandstone Mb				
		Gypsiferous Shale Mb		Kuldhar Mb		
		Ridge Sandstone Mb				
		Shelly Shale Mb				
Bathonian	Patcham Fm	Raimalro Limestone Mb/Sponge Limestone Mb		Cross-bedded sandy pack- to grainstones		
	Goradongar Fm	Purple Sst/Gadaputra Sst Mb/Echinoderm Packstone		Badabag Member	Jaisalmer Fm	3
	Jhurio Fm	JCL				
		Goradongar Yellow Flagstone Member	Fort Mb	bioturbated micrite unit		
Bajocian	Kaladongar Fm	Leptosphinctes-bearing Pebby Rudstone	Joyan Mb	Isastrea bernardiana-bearing rudstone		2
Early-Middle Jurassic		Babia Cliff Sst Mb		Hamira Mb		
		Kaladongar Sst Mb		Thaiat Mb		
		Dingy Hill Mb		Odania Mb	Lathi Fm	1
Precambrian		Basement rocks				

**Figure 2** Lithostratigraphy of Jurassic rocks of western Kachchh and Jaisalmer basins<sup>[6,12–15]</sup>. Numbers 1–4 refer to the four marker horizons in the western Kachchh and Jaisalmer basins mentioned in the text. Fm, Formation; Mb, Member; Sst, Sandstone; JCL, Jumara coral limestone; HGS, Hardground surface.

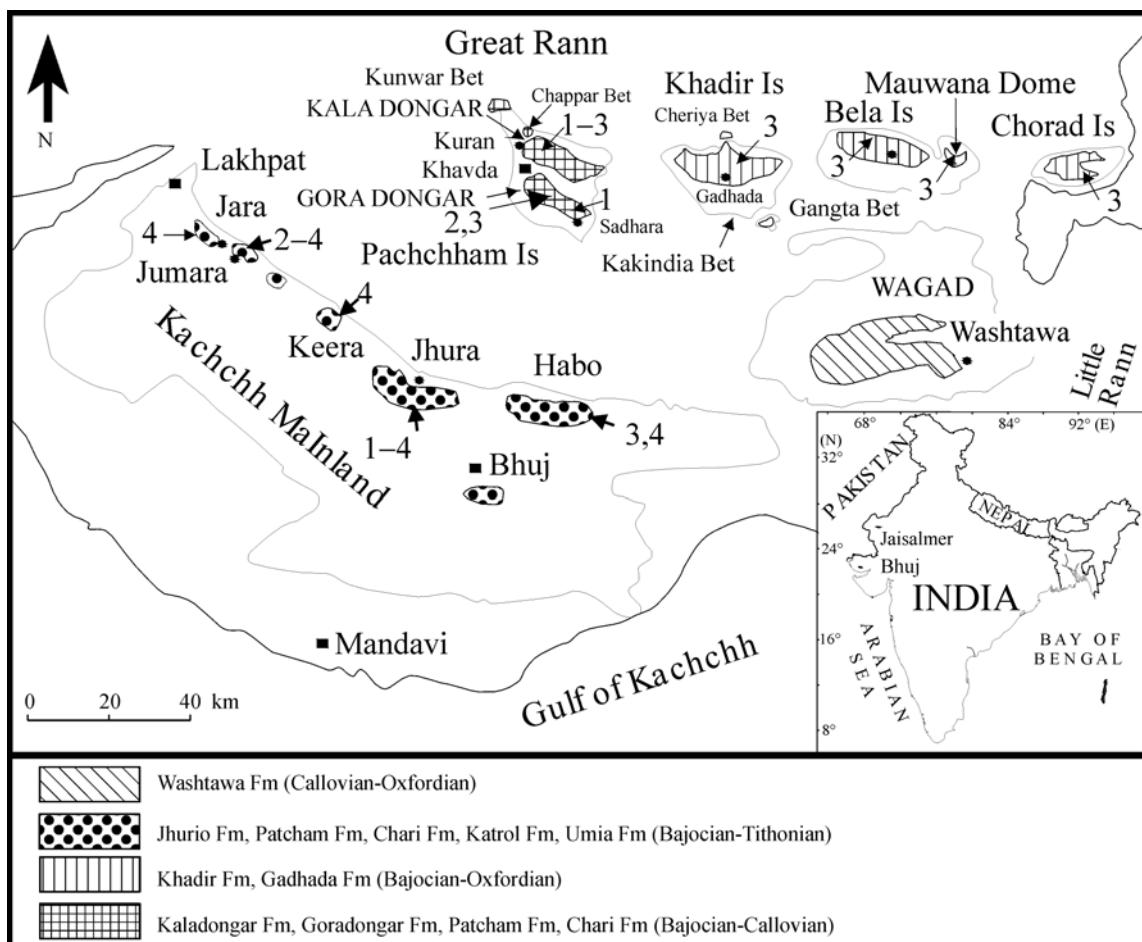
Kachchh Basin is more complete and more fossiliferous than that of the Jaisalmer Basin. The reason for the former is local tectonics that exerted a major control on the paleogeography of the area (Figure 1). The Kachchh Basin is an E-W-oriented graben structure that formed during the Late Triassic as a result of rifting between Africa and India<sup>[1–3]</sup>. The Mesozoic sediments (about 3000 m thick) of the Kachchh Basin are displayed in three anticline belts running east-west. They are, from north to south, the Island belt, the Mainland, and the

southern anticlinal belt south of Bhuj.

The Jaisalmer Basin, in contrast, is a northward sloping shelf basin, tectonically divisible into four structural units (Figure 1) as revealed by geophysical investigations conducted by the Oil and Natural Gas Commission<sup>[16–18]1)</sup>. The Mesozoic sediments (about 3000 m thick) are exposed on the raised Mari-Jaisalmer Arch extending NW-SE through the central part of the basin<sup>[5,6,14]</sup>.

The Kachchh Basin had a more open marine character

1) See footnote 1) on page 1925.



**Figure 3** Locality map of the Kachchh Basin showing Jurassic outcrops. Numbers 1–4 refer to localities of the four marker horizons in the Kachchh Basin mentioned in the text.

than the Jaisalmer Basin due to its greater accommodation space. In the Jaisalmer Basin, sedimentation was frequently interrupted by phases of erosion and non-sedimentation. Consequently, intrabasinal correlation of the sedimentary units is possible in the Kachchh Basin, but not in the Jaisalmer Basin. However, by comparing the stratigraphic succession of both basins and the biofacies of coeval sedimentary units, it becomes clear that the depositional history of the basins was, to some extent, controlled by the same factors. The present paper aims, through identifying some marker beds common to both basins, to identify the main factors controlling sedimentation history in the area.

## 1 Interbasinal marker intervals in the Kachchh and the Jaisalmer basins

Four marker beds have been identified, which occur within the Jurassic sedimentary succession of both ba-

sins. They can be used for interbasinal correlation and indicate a common control of the sedimentation history.

### 1.1 Cross-bedded rudstone with large reworked coral heads, erosional surfaces and basement pebbles

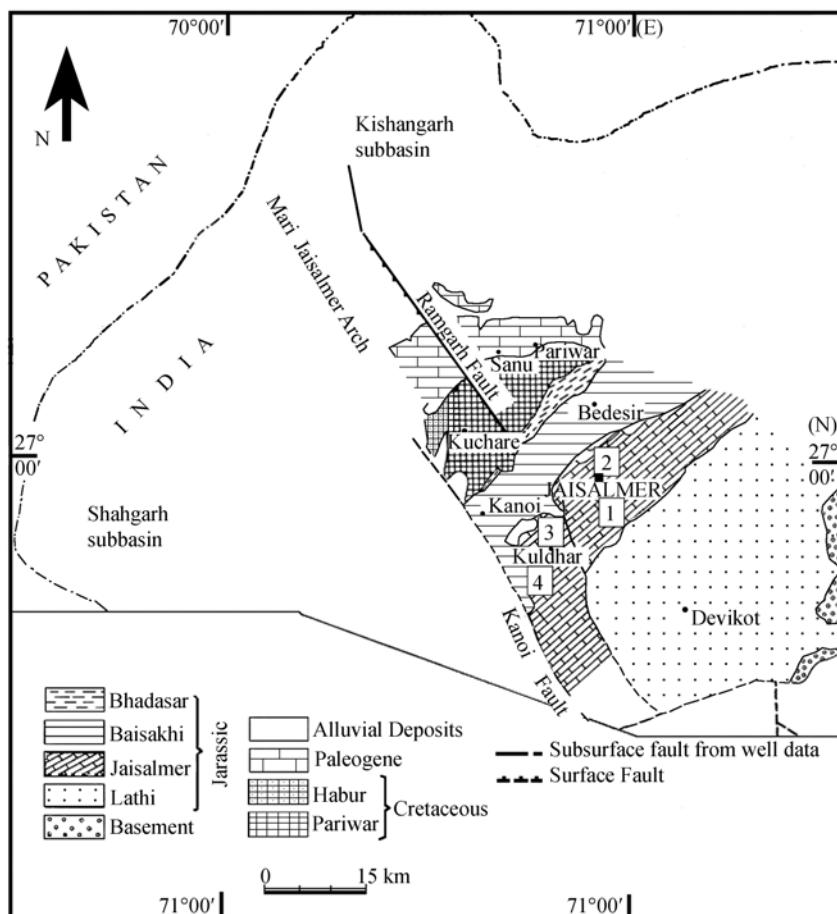
The pebbly rudstone unit with coral heads of *Isastrea bernardiana* and the ammonite *Leptosphinctes* of the Kaladongar Formation, also called Leptosphinctes Bed (western Kachchh Basin)<sup>[4,12]</sup> and the *Isastrea bernardiana*-bearing rudstone of the Jaisalmer Formation (Jaisalmer Basin)<sup>[6,7,19]</sup>, has been dated as Late Bajocian (Figure 2). The Leptosphinctes Bed is a marker bed exposed along the east-west extending northern scarp of Kala Dongar, Pachchham Island in the northern anticlinal belt (locality 1 in Figure 3). This unit, which marks a major marine transgression in the basin, can be followed along an onshore-offshore gradient southward towards the eastern part of Gora Dongar (Pachchham Island) and SSE-ward to the Jhura Dome of Kachchh Mainland (lo-

locality 1 in Figure 3). The *Isastrea bernardiana*-bearing bio-rudstone is also a marker bed exposed in the south-eastern part of the raised Mari-Jaisalmer Arch, i.e., in the southeastern part of Jaisalmer city (locality 1 in Figure 4). This unit also marks the first major marine transgression in the basin. In both basins the units therefore correspond to deposits of a transgressive systems tract (TST).

In both basins, this first, more than 1-m-thick, cross-bedded rudstone unit of the basal part of the Jurassic succession contains several erosion surfaces, coral-heads, and overlies continental or brackish to marginally marine sediments. The corals are large, reworked (bored and abraded) heads of *Isastrea bernardiana*. As mentioned earlier<sup>[19]</sup>, the taxon is confined worldwide to the Late Bajocian. The contemporary unit in the Kachchh Basin has yielded the ammonite *Leptosphinctes* sp. of the Late Bajocian age<sup>[4]</sup>. In the Kachchh Basin the unit contains basement pebbles<sup>[12]</sup>.

## 1.2 Bioturbated micrites with anomalodesmata bivalves

The Middle to Upper Bathonian Goradongar Yellow Flagstone Member (Goradongar Formation) of the western Kachchh Basin is exposed in Kala Dongar, Gora Dongar (Pachchham Island), and in the Jhura and Jumara domes (Kachchh Mainland). Age-equivalent bioturbated micrites in the middle part of the Fort Member (Jaisalmer Formation) of the Jaisalmer Basin are exposed along a ridge 0.5 km north of Jaisalmer city (Figure 2, locality 2 in Figures 2 and 3). In general, the rocks represent deposits of the maximum flooding zone (MFZ)<sup>[7,12]</sup>. They yield a high-diversity fauna, composed of both autochthonous and allochthonous elements. Occasionally, due to sediment starvation, the preserved sedimentary package is not very thick (not more than a few meters). However, the bioturbated micrite units of the Goradongar Yellow Flagstone Member (5–44 m) and of the Fort Member (8 m) are similar in sediment



**Figure 4** Geological map of the Jaisalmer Basin<sup>[14]</sup>. Numbers 1–4 refer to localities of the four marker horizons in the Jaisalmer Basin mentioned in the text.

composition and primary sedimentary structures, and contain a similar bivalve association<sup>[5, 12]</sup>. The typical Middle Bathonian ammonite association of the Kachchh Basin comes from this horizon, comprising *Procerites* (*Gracilisphinctes*) *arkelli* Collignon, *Procerites* cf. *schloenbachi* (Grossouvre), *Clydoniceras pachchhamense* Pandey and Agrawal, *Clydoniceras triangulare* Pandey and Agrawal, *Clydoniceras* sp., *Micromphalites* (*Clydomphalites*) cf. *clydocromphalus* Arkell, *Micromphalites* (*Clydomphalites*) sp. indet., and *Bullatimorphites* (*Khericeras*?) n. sp. A<sup>[4,20–26]</sup>. The characteristic bivalve association occurs also in the coeval horizon in the Jaisalmer Basin<sup>[5,22,27]</sup>, consisting of *Pholadomya* (*Pholadomya*) *kachchensis* Pandey et al., *P.* (*Bucardomya*) *lirata* J. de C. Sowerby, *Agrawalimya pseudo-sulcata* Singh et al., *Homomya pachchhamensis* Pandey et al., *Ceratomya wimmensis* (Gilliéron), *Ceratomyopsis striata* (d'Orbigny), and *Pleuromya uniformis* J. de C. Sowerby, etc.<sup>[28,29]</sup>.

### 1.3 Trough-crossbedded, sandy packstone to grainstones with megaripple surfaces

The Upper Bathonian Raimalro Limestone Member of the Goradongar Formation can be traced from Kala Dongar, Gora Dongar (Patcham Island) to the Habo, Jhura and Jumara domes of Kachchh Mainland (western Kachchh Basin) and to the Khadir, Bala and Chorad islands of the eastern Kachchh Basin (Figure 2, locality 3 in Figure 3)<sup>[12]</sup>. Time-equivalent is the basal limestone/sandstone unit of the Jaisalmer Formation at Kuldhar in the Jaisalmer Basin (Figure 2, locality 3 in Figure 4)<sup>[30]</sup>. The Raimalro Limestone Member is a 2–15 m thick, large-scale trough-crossbedded, sandy packstone to grainstone with occasional shell lenses and chert nodules in layers and topped by a mega-ripple surface. This unit corresponds to a TST. The overlying sediments of the Chari Formation are bioturbated, fine-sandy marly siltstone with thin intercalations of laminated packstones and grainstones of the MFZ, followed by storm-dominated sediments of the highstand systems tract (HST).

Similarly, the basal limestone/sandstone unit in the Kuldhar section belonging to the Jaisalmer Formation comprises cross-bedded, fine-grained sandstones to bio-oooid-packstone with a mega-ripple surface, which represent TST deposits. They are overlain by thin beds of fossiliferous, bioturbated wackestones, packstones and silty marls, mostly with sharp lower surfaces, some

with shell concentrations, reworked and bored clasts, and with two hardground surfaces in the basal part (MFZ, followed by HST). Both units have been assigned to the Upper Bathonian based on ammonite evidence such as *Macrocephalites triangularis* Spath and *Sivajiceras congener* (Waagen)<sup>[12,30–33]</sup>.

### 1.4 Ferruginous ooid-bearing carbonate sediments with hardground surfaces

The Dhosa Oolite member (Chari Formation) in the western Kachchh Basin, exposed in the Habo, Jhura, Keera, Jumara, and Jara domes on Kachchh Mainland (Figure 2, locality 4 in Figure 3), and the middle part of the Jajiya Member (Jaisalmer Formation) of the Jaisalmer Basin exposed south of Kuldhar village (Figure 2, locality 4 in Figure 4) both represent the Oxfordian time interval.

In general, ferruginous ooids occur at several levels in the marine sedimentary succession of both basins but their abundance during the Oxfordian, together with hardgrounds and other features documenting period of non-sedimentation and erosion in both basins, is remarkably similar. The Dhosa Oolite member of the Kachchh Basin, which consists predominantly of sandy carbonates and is 4–20 m thick, can be followed laterally for more than 100 km from west to east<sup>[11,12,34]</sup>. The member is a highly condensed unit and, due to its wide lateral extension, is an excellent marker horizon<sup>[12]</sup>. As it comprises a considerable time span, several TST-HST sequences are involved. In general, however, the Oxfordian is the stage with the highest relative sea level and maximum transgression in the two basins. As a result, sediment starvation, hardground formation, and development of extensive stratigraphic lacunae are common features.

The coeval unit in the Jaisalmer Basin is the middle part of the Jajiya Member. Three hardgrounds have been recorded from this level. The hardground-bearing unit consists of bioturbated mudstone to rudstone, rich in ferruginous ooids, and yields ammonites comparable to those from the Dhosa Oolite of the Kachchh Basin. As a comparison, extensive ferruginous ooide beds are present in the Southern Hemisphere Jurassic deposits<sup>[35]</sup>, and have probably a global extent in some cases.

Identification of Oxfordian taxa of the present collection has not been completed. However, similar ammonites have been recorded by earlier workers<sup>[8,36–38]</sup> from these horizons in the two basins. The taxa include the

Lower Oxfordian *Peltoceratoides* (*Peltoceratoides*) *semirugosus* (Waagen), the Middle Oxfordian *Mayaites* (*Mayaites*) *maya* (J. de C. Sowerby), *Dhosaites elephantoides* Spath, *Epimayaites* sp., and *Alligaticeras* sp., and the Upper Oxfordian *Perisphinctes* (*Dichotomoceras*) *alterneuplicatus* Prasad, *Torquatisphinctes alterneuplicatus* (Waagen), *Dichotomosphinctes* aff. *subhelenae* Spath, etc.

## 2 Discussion

The similar coeval biofacies at certain levels in the two basins points to a similar depositional history, controlled by the same set of factors. This is surprising, as the basins represent different tectonic regimes: the Kachchh Basin is a rift basin and the Jaisalmer basin a shelf basin. Factors controlling facies development include the rate of subsidence, eustatic sea-level fluctuations, local tectonics, and climate. Apparently the rates of subsidence were similar for both basins, which is supported by nearly identical thickness (about 3000 m) of the Mesozoic sedimentary successions. Similar biofacies implies similar climatic conditions, in particular with respect to temperature-controlled carbonate production and input of terrigenous sediment caused by elevated precipitation rates. As the distance between the two basins was about 2° latitude and both were situated in the subtropical belt during the Jurassic<sup>[39, 40]</sup>, they should have experienced similar climatic conditions considering that during the Jurassic latitudinal climatic gradients were less pronounced than they are today<sup>[41–43]</sup>.

Terrigenous input is also controlled by uplift of the hinterland due to local tectonic movements. Consequently, it appears that during the time intervals represented by the four marker horizons, local tectonics did not play a significant role and that these intervals were times of tectonic quiescence in the Kachchh rift basin. This leaves eustatic sea-level fluctuations as a major

controlling factor. However, placing the marker intervals against the global sea-level curve of Hardenbol et al.<sup>[44]</sup>, the phases of relative sea-level rise and highstand documented by the four marker intervals do not coincide with phases of major global transgressions. Most likely, the synchronicity of biofacies in the two basins is the result of a combination of factors affecting both regions, i.e., eustatic sea-level fluctuations, subsidence pattern, and climate.

## 3 Conclusions

The two adjacent Jurassic sedimentary basins of Kachchh and Jaisalmer on the northwestern part of Indian craton were inundated by the sea at the same time, in the late Early Jurassic. Four marker horizons have been identified, which exhibit very similar biofacies in both basins and have been proven to be synchronous based on fossil evidence. They are: (1) cross-bedded rudstones with reworked coral heads, erosional surfaces, and basement pebbles (TST of Late Bajocian); (2) bioturbated micrites with anomalodesmatan bivalves (MFZ of Middle to Late Bathonian); (3) trough-crossbedded, sandy pack- to grainstones with megaripple surfaces (TST of Late Bathonian); (4) ferruginous ooid-bearing carbonates with hardground surfaces (TST of Oxfordian).

The four marker intervals owe their existence most likely to a combination of factors, in particular changes in the rate of subsidence, eustatic sea-level fluctuations, and climate changes, which affected the region in the same way. At the same time, tectonic activity in the Kachchh rift basin cannot have been strong enough to produce marked differences in the biofacies pattern between the two basins.

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- 1 Biswas S K. Rift basins in the western margin of India and their hydrocarbon prospects. *Am Assoc Petrol Geol Bull*, 1982, 66: 1497–1513
- 2 Biswas S K. Stratigraphy and sedimentary evolution of the Mesozoic basin of Kutch, western India. In: Tandon S K, Pant C C, Kashyap S M, eds. *Stratigraphy and Sedimentary Evolution of Western India*. Nainital: Gyanodaya Prakashan, 1991. 74–103
- 3 Biswas S K. Geology of Kutch. Dehradun: K.D. Malaviya Institute of Petroleum Exploration, Vol. 2, 1993. 1–450
- 4 Singh C S P, Jaitly A K, Pandey D K. First report of some Bajocian-Bathonian (Middle Jurassic) ammonoids and the age of the oldest sediments from Kachchh, Western India. *Newslett Stratig*, 1982, 11: 37–40
- 5 Pandey D K, Sha J G, Choudhary S. Depositional environment of Bathonian sediments of the Jaisalmer Basin, Rajasthan, western India. *Prog Nat Sci*, 2006, 16(Spe Iss): 163–175
- 6 Pandey D K, Sha J G, Choudhary S. Depositional history of the early part of the Jurassic succession on the Rajasthan Shelf, western India. *Prog Nat Sci*, 2006, 16(Spe Iss): 176–185
- 7 Pandey D K, Choudhary S. Sequence stratigraphic framework of Lower to lower Middle Jurassic sediments of the Jaisalmer Basin, India. *Beringeria*, 2007, 37: 121–131

- 8 Krishna J. An overview of the Mesozoic stratigraphy of Kachchh and Jaisalmer Basins. *J Palaeontol Soc India*, 1987, 32: 136–152
- 9 Fürsich F T, Oschmann W. Shell beds as tool in facies analysis: The Jurassic of Kachchh, western India. *J Geol Soc London*, 1993, 150: 169–185
- 10 Fürsich F T, Oschmann W, Jaitly A K, et al. Faunal response to transgressive-regressive cycles: Example from the Jurassic of western India. *Palaeogeogr Palaeoclimat Palaeoecol*, 1991, 85: 149–159
- 11 Fürsich F T, Oschmann W, Singh I B, et al. Hardgrounds, reworked concretion levels and condensed horizons in the Jurassic of Western India: Their significance for basin analysis. *J Geol Soc London*, 1992, 149: 313–331
- 12 Fürsich F T, Pandey D K, Callomon J H, et al. Marker beds in the Jurassic of the Kachchh Basin, western India: Their depositional environment and sequence-stratigraphic significance. *J Palaeontol Soc India*, 2001, 46: 173–198
- 13 Biswas S K. Mesozoic rock-stratigraphy of Kutch, Gujarat. *Quarterly J Geol, Mineral Metallurg Soc India*, 1980, 49: 1–51
- 14 Das Gupta S K. A revision of the Mesozoic-Tertiary stratigraphy of the Jaisalmer Basin, Rajasthan. *Indian J Earth Sci*, 1975, 2(1): 77–94
- 15 Waagen W. Jurassic fauna of Kutch. The Cephalopoda. *Mem Geol Surv India, Palaeontol Indica*, 1873–1875, Ser 9, 1(1–4): 1–27
- 16 Rao R V. Subsurface stratigraphy, tectonic setting and petroleum prospects of the Jaisalmer area, Rajasthan, India. *Proc IV Symp Devel Petrol Resou Asia and Far East Canberra, Australia*, 1972, 41 (1): 366–371
- 17 Sinha A K, Yadav R K, Qureshi S M. Status of exploration in South Shahgarh Subbasin of Jaisalmer Basin, Rajasthan. In: Biswas S K, Dave A, Garg P, et al, eds. *Proceedings of Second Seminar on Petroleum Basins of India 2*. Dehra Dun: Indian Petroleum Publishers, 1993. 285–333
- 18 Singh A K, Sethi J R, Rai A K, et al. An overview of exploration and exploitation Strategy for hydrocarbons in ONGC acreages of Jaisalmer Basin, Rajasthan. *Proceedings of the National Seminar on Oil, Gas & Lignite Scenario with Special Reference to Rajasthan*. Jaipur: Social Policy Research Institute, 2005. 53–68
- 19 Pandey D K, Fürsich F T. Bajocian (Mid Jurassic) age of the lower Jaisalmer Formation of Rajasthan, Western India. *Newslett Stratig*, 1994, 30: 75–81
- 20 Singh C S P, Pandey D K, Jaitly A K. Discovery of *Clydoniceras* Blake and *Gracilisphinctes* Buckman (Bathonian-Middle Jurassic ammonites) in Kachchh, Western India. *J Paleont*, 1983, 57: 821–824
- 21 Pandey D K, Agrawal S K. On two new species of the middle Jurassic ammonite genus *Clydoniceras* Blake from Kachchh, Western India. *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte*, 1984. 321–326
- 22 Pandey D K, Agrawal S K. Bathonian-Callovian molluscs of Gora Dongar, Pachchham “Island” District Kachchh, Gujarat. *Quarterly J Geol, Min Metal Soc India*, 1984, 56: 176–196
- 23 Jaitly A K, Singh C S P. On the Bathonian (Middle Jurassic) ammonites *Micromphalites* Buckman and *Gracilisphinctes* Buckman from Kachchh, Western India. *Geol Mag*, 1984, 121(4): 319–321
- 24 Jaitly A K. Indomya, a new subgenus of Pholadomya from Middle Jurassic of kachchh, W. India (Bivalvia: Pholadomyidae). *Veliger*, 1986, 28(4): 457–459
- 25 Pandey D K, Westermann G E G. First record of Bathonian *Bullatimorphites* (Jurassic Ammonitina) from Kachchh, India. *J Paleont*, 1988, 62: 148–150
- 26 Pandey D K, Callomon J H. Contribution to the Jurassic of Kachchh, Western India. III. The Middle Bathonian ammonite families Clydoniceratidae and Perisphinctidae from Pachchham Island. *Beringeria*, 1995, 16: 125–145
- 27 Pandey D K, Heinze M, Fürsich F T. Contribution to the Jurassic of Kachchh, Western India. V. The bivalve fauna. Part II. Subclass Anomalodesmata. *Beringeria*, 1996, 18: 51–87
- 28 Fürsich F T, Oschmann W, Pandey D K, et al. Palaeoecology of Middle to lower Upper Jurassic macrofaunas of the Kachchh Basin, western India: An overview. *J Palaeont Soc India*, 2004, 49: 1–26
- 29 Fürsich F T, Pandey D K, Callomon J H, et al. Contributions to the Jurassic of Kachchh, Western India. II. Bathonian stratigraphy and depositional environment of the Sadhara Dome, Pachchham Island. *Beringeria*, 1994, 12: 95–125
- 30 Jain S. Integrated Jurassic biostratigraphy: A closer look at nanno-fossil and ammonite evidences from the Indian subcontinent. *Current Sci*, 2008, 95(2): 326–331
- 31 Agrawal S K, Pandey D K. Biostratigraphy of the Bathonian - Callovian Beds of Gora Dongar in Pachchham “Island”, District Kachchh Gujarat. *Proc Indian Nat Sci Acad Part A*, 1985, 51(5): 887–903
- 32 Callomon J H. On *Perisphinctes congener* Waagen, 1875, and the age of the Patcham Limestone in the Middle Jurassic of Jumara, Kutch, India. *Geologische Blätter von NO-Bayern*, 1993, 43(1–3): 227–246
- 33 Pandey D K, Fürsich F T. Distribution and succession of Jurassic rocks in Gora Dongar, Pachchham “Island”, Kachchh, India. *J Geol Soc India*, 1998, 51: 331–344
- 34 Singh I B. Dhosa Oolite — A transgressive condensation horizon of Oxfordian age in Kachchh, Western India. *J Geol Soc India*, 1989, 34: 152–160
- 35 Jansson I M, McLoughlin S, Vajda V. Early Jurassic annelid cocoons from eastern Australia. *Alcheringa*, 2008, 32: 285–296
- 36 Kachhara R P, Jodhwat R L. On the age of Jaisalmer Formation, Rajasthan, India. In: *Proceedings of IX Indian Colloquium on Micropalaeontology and Stratigraphy*. Department of Geology, University of Rajasthan Udaipur, 1981. 235–247
- 37 Krishna J, Pathak D B, Pandey B, et al. Transgressive sediment intervals in the Late Jurassic of Kachchh, India. *Geol Res Forum*, 2000, 6: 321–332
- 38 Prasad S. Ammonite biostratigraphy of Middle to Late Jurassic rocks of Jaisalmer Basin, Rajasthan, India. *Mem Geol Sur India*, 2006, 52: 1–146
- 39 Ziegler A M, Eshel G, Rees P M, et al. Tracing the tropics across land and sea: Permian to present. *Lethaia*, 2003, 36: 227–254
- 40 Wang Y, Mosbrugger V, Zhang H. Early to Middle Jurassic vegetation and climatic events in the Qaidam Basin, Northwest China. *Palaeogeogr Palaeoclimat Palaeoecol*, 2005, 224: 200–216
- 41 Hallam A. A review of Mesozoic climates. *J Geol Soc London*, 1985, 142: 433–445
- 42 Vajda V. Aalenian to Cenomanian palynofloras of SW Scania, Sweden. *Acta Paleont Polonica*, 2001, 46: 403–426
- 43 Jansson I M, McLoughlin S, Vajda V, et al. An Early Jurassic flora from the Clarence-Moreton Basin, Australia. *Rev Palaeobot Palynol*, 2008, 150: 5–21
- 44 Hardenbol J, Thierry J, Farley M B, et al. Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins In: de Graciansky P C, Hardenbol J, Jacquin T, et al, eds. *Mesozoic and Cenozoic Sequence Stratigraphy of European Basins*. Spec Publ SEPM 60. 1998